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THE HABITS AND NATURAL HISTORY OF STICHOSTEMMA.

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A SMALL fresh-water nemertean, undoubtedly *Stichostemma asensoriatum* Montgomery ('96), is found very abundantly in one of the park lagoons in Chicago.

The animal has proved to be a favorable form for experimental study, and in the course of such work during the past two years a number of observations upon its habits and natural history have been made. These observations are given here in the belief that a connected account of the natural history of a single form is of value because it brings together a series of facts which, though important, often receive only incidental attention in connection with other work, or are ignored altogether, and because it affords a basis for further study.

Montgomery ('96) has given a brief description of a new American species of fresh-water nemertean which he called *Stichostemma asensoriatum.* He regards Silliman's *Tetrastemma aquarum dulcium* ('85) as insufficiently characterized, but believes that it may be closely allied to *S. asensoriatum.* The species which forms the subject of this paper agrees with Montgomery's description of *S. asensoriatum* in all respects except that it is not protandric, while Montgomery believes *S. asensoriatum* to be protandric like *S. eilhardi.* Böhmig ('98) has accepted Montgomery's genus Stichostemma for his species *S. græcense,* but as *S. græcense* is not protandric, Böhmig holds that the existence of protandry should not be regarded as a characteristic of the genus. In a personal communication very kindly made in answer to an inquiry of my own, Dr. Montgomery expresses himself as of the opinion that the presence or absence of protandric hermaphroditism is a point of minor importance. The revised genus diagnosis of Stichostemma as given by Böhmig ('98) is as follows:

"Augenzahl veränderlich, gewöhnlich mehr als 4; 9 oder 10 Rüsselnerven; das Rhyncocoelom erstreckt sich nicht bis an das Körperende; die Nephridien dehnen sich von der Gegend des Gehirns bis zur hinteren Körperspitze aus; zwitterig, ovipar." The species found in the vicinity of Chicago agrees with *S. græcense* in not being protandric, but since I cannot find that it differs in other respects from the description given by Montgomery of *S. asensoriatum*, I am inclined for the present to regard the two as identical. It appears probable, moreover, that *S. asensoriatum* Montgomery is identical with *Tetrastemma aquarum dulcium* Silliman. In any case the two forms are closely allied, as Montgomery admits.

The species under consideration is a slender worm, attaining often a length of 20 mm. (Montgomery gives the maximum length as 18 mm.). It varies in color from a light yellowish, almost cream-color, in the smaller specimens, to a deep orange-red in many of the large individuals. Even in the most brilliantly colored specimens, however, the terminal regions of the body are more yellowish than other parts. The reddish coloration is especially distinct in the nervous system. In many of the larger specimens the region of the brain can be distinguished by the naked eye on account of its deeper coloring. Individuals in which the eggs are nearly ripe show scarcely a trace of the reddish tint, being almost pure yellow in color. Animals kept in the laboratory for a long time without food usually become more or less brownish, owing to the appearance of black pigment in the integument. This pigment is occasionally found in newly captured specimens. I am inclined to believe that its appearance is connected in some manner with the lack of food.

The usual number of eyes is six, the anterior pair being the largest and the posterior pair the smallest. Variation in the number of eyes, or at least in the number of pigment spots, is of frequent occurrence. Specimens with only four eyes sometimes occur, but are rare. In case eight symmetrically placed eyes are present, the anterior pair is usually small and situated a short distance in front of the largest pair. The eyes are very often unsymmetrically placed or differ in number on the two sides of the head. Variation in the number of pigment spots can often be observed in a single individual. One or more of the spots may divide, or in some cases a number of small masses of pigment appear in place of a single pigment spot, in consequence of a kind of fragmentation. One of these smaller masses may increase to the size of the whole, while the others disappear. Migration of these masses is often observed. A more complete account of these observations is reserved for a future time.

The body of the worm is very transparent. The alimentary canal, blood vessels, terminal nephridial organs, nervous system, gonads, the rhyncocœl, and the proboscis, with principal and accessory stilets, can be clearly seen in the living animal under slight pressure. For some time past I have employed the form for class work on account of the ease with which its internal anatomy can be studied.

The points of difference between this form and *S. eilhardi* as given by Montgomery ('96) are as follows: (1) The absence of the supraoral sense pit, which suggested the specific name "asensoriatum." (2) The cephalic gland is not as voluminous as in *S. eilhardi*, and has not one main efferent duct, but the ducts of the individual gland cells penetrate the body epithelium independently of one another, in the manner of subcuticular gland cells; the external openings of these cells lie at the anterior end of the head. The want of a main efferent duct, formed by the fusion of the individual cell ducts, might be explained by the absence of the supraoral sense pit, since in most metanemerteans the main duct discharges at the base of this pit. (3) The pigment of the body epithelium occurs exclusively in the supporting cells and is not found at all in the interstitial tissue. (4) Those gland cells corresponding to what I have termed "gland cells 3" in *S. eilhardi* are not egg-shaped, as in that species, but have an elongated narrow form; in structure and in their color reaction to stains they show a close similarity to the cells of the cephalic gland: thus, they stain intensely with hæmatoxylin, and with the triple stain of Flemming (safranin, gentian violet, orange G) combine with the safranin and not with the violet. (5) The stilet basis is slightly constricted medially. (6) There are ten instead of nine longitudinal nerves in the proboscis.

These differences do not concern the general appearance, so that the figure of *S. eilhardi* given by Montgomery ('95, Taf. VIII, Fig. 17) might serve equally well as a general diagram of the structure of *S. asensoriatum*.

OCCURRENCE AND DISTRIBUTION.

During the early autumn of 1899 Stichostemma was found in great abundance in one of the lagoons in Jackson Park, Chicago, which has free communication with Lake Michigan. Since that time it has been present in the lagoon at all seasons of the year. Large numbers are found in masses of Spirogyra or other filamentous algæ, and often, though less commonly, the animals are found among Elodea. They are most numerous along the shore where the water is only a few inches deep. Their presence here is probably due to the higher temperature of the shallow water near the shore and the consequent more luxuriant growth of the vegetation which they frequent. Their food, which consists of species of Nais, is very abundant in the lagoon under the same conditions, and probably also, directly or indirectly, constitutes a factor in the local distribution.

The distribution about the lagoon is rather irregular and uneven. In some spots the worms are so abundant that hundreds may be taken from a single liter of the aquatic vegetation. In other spots, apparently equally well suited to these forms, only a few individuals or none at all are found. While these areas are rather definite during a single season, the worms do not always reappear in the same spot in succeeding years. It is usually necessary to hunt for the favorable localities anew each year.

The seasonal distribution is very definite. During the later summer and autumn the animals are usually very abundant, young and old together. They do not disappear from along the banks until actual freezing occurs. When the ice forms, many of the worms are undoubtedly destroyed, though a large number of them must reach deeper water, where they continue to live beneath the ice during the winter. The lagoon is twelve to fifteen feet deep in many places, and no freezing occurs in the deeper parts. There is no evidence that the worms are capable of enduring actual freezing. After the first appearance of ice in the lagoon I have chopped out and thawed masses of the vegetation in which the worms had been abundant a few days before, but which were frozen solidly into the ice when removed. In aquaria and jars prepared from these no worms ever appeared. During the winter of 1899–1900 a part of the lagoon remained open until about the middle of January, although the weather was cold and the remainder was covered with several inches of ice. Up to this time the worms were found here in abundance. Later this area was covered with ice a foot or more in thickness, and the bottom was also frozen in the shallower parts, and at this time no worms were obtained from the region.

It is possible that the worms burrow into the mud, but samples of the mud taken at various times during the winter have never yielded a specimen. I have been unable to examine fully the deepest parts of the lagoon, but believe that the animals remain more or less active there during even the colder months.

The worms reappear near the shore in large numbers very soon after the ice begins to melt. In 1900 the lagoon was covered with from twelve to sixteen inches of ice on March 20. By March 26 the ice had melted along the shores, leaving some two or three feet of open water from six inches to a foot in depth. At this time large numbers of worms were found in this open area, nearly all of them large specimens with well-developed eggs, whereas the worms taken in January are of various sizes and mostly with very small eggs or none at all. The small worms taken in January are the young of the preceding autumn which have not attained full size. If the worms had remained inactive until the ice melted, it is difficult to understand how their increase in size and the growth of the eggs could have occurred in so short a time as three or four days. I believe, therefore, that they must have spent the month of February and the early part of March in the deeper parts of the lagoon, reappearing at once near the surface as the temperature of the water began to rise. The small naids which form their food can be taken at all times through the winter from beneath the ice, so that so far as food is concerned Stichostemma is well supplied during the winter months.

Apparently, then, the young of the preceding autumn reach their full size during the winter, reappearing near the surface with nearly ripe eggs as soon as the ice disappears.

During the winter of 1900–1901 the lagoon was wholly covered with six to eight inches of ice before the end of December, and the temperature during the greater part of January and practically the whole of February was far below 32°. The ice became exceptionally thick and did not disappear till near the end of March. The worms were not found along the shore until April 12, and then only a few appeared, all of them large and filled with eggs which were about half grown. During the early part of December, 1900, before the lagoon was completely frozen over, the worms were more abundant than I had ever found them before. Their late appearance and small numbers in April, 1901, must probably be attributed to the protracted cold weather and the thickness of the ice in the lagoon.

During the months of May and June comparatively few full-grown specimens are found, but the young are increasingly abundant as the season advances. These become sexual about July 1 or a little earlier. By this time nearly all the old worms which survived the winter have disappeared. During the remainder of the summer the worms continue to increase in numbers until freezing kills them or drives them to deeper water.

There is no evidence that the worms possess the power of entering upon a resting stage of any kind which is capable of enduring freezing without injury, though there are some facts that indicate the possibility that they may become more or less quiescent for a short time. When the animal is brought under conditions which are disagreeable to it, or is irritated, it secretes a large amount of slime and in many cases becomes enclosed in a covering of slime, which gradually contracts and becomes more dense until it resembles a cyst. Within this the worm may remain for some weeks, either moving slowly or not at all, or it may leave in a few days. Left in jars of clear water without algæ, the animals are likely to make these slime coverings repeatedly. As will appear below, I believe that the fact that the animal is disinclined to leave the slime is a thigmotactic reaction. Violent stimulation will often induce removal, or the slime may be picked apart with needles, thus freeing the animal, which is active and normal in appearance in every respect. In many cases mutilated specimens or animals in impure water form these coverings and remain in them until death.

It is possible that the worms may form these "cysts" about themselves during the winter. These do not, however, enable them to resist freezing and do not serve as a protection against desiccation, as will appear below. It is difficult to understand how the animal is better protected within this "cyst," except, perhaps, as regards predatory enemies, than it is under the usual conditions. While this process is perhaps to be regarded as showing the manner in which the process of encystment may arise, I think it is certain that in its present development this slime covering is of little value as a cyst. The causes and method of its formation are discussed below.

Movements.

Locomotion forward is accomplished principally by means of the cilia with which the body is covered. During the forward movement the head is turned slightly from side to side in regular succession, and as the body follows the same course the movement as a whole is distinctly sinuous, the body showing altogether four or five curves to left and right at any given time. It is probable that under normal conditions the sinuous character of the movement is a distinct aid in locomotion. In crawling through masses of algæ the lateral movements of the head will, of course, enable the animal to find the interstices more readily, while the sinuous bending of the body affords a firmer support and a greater power for forcing a way among the tangled threads. The value of these movements in enlarging the field of direct stimulation and contact is evident. The animal crawls along the bottom of a jar with the ventral surface uppermost almost as often as in the other position. It is unable to support itself free in the water, although it often drops from the surface to the bottom, making the usual crawling movements during the descent. During all forward movement the head is continually making rapid searching movements in all directions.

Backward movement is accomplished in a manner entirely different from that just described for forward locomotion, *viz.*, by muscular contractions.

The muscular activities concerned in backward locomotion consist of a series of peristaltic waves. A contraction of the circular muscles near the posterior end occurs, and the end is thrust backward; then a wave, consisting of strong contractions of the longitudinal and relaxation of the transverse muscles, producing a shortening and thickening of the region affected, begins at the posterior end of the body and travels forward. The whole process is quickly repeated, and in continued backward movements three or four of these peristaltic waves may be visible on the body at one time. On a smooth surface like glass these movements are rather ineffective, but it is easy to see how, under natural conditions, the posterior end of the body becomes more or less completely fixed as soon as increase in size begins and the other portions are drawn back to it.

The body is extremely contractile, and different parts are capable of independent contraction. In the reassumption of the extended position after contraction, the extension usually begins at the anterior end and proceeds backward along the body as the head advances.

Movements of the proboscis within the rhyncocœl are very common. Contraction of the circular muscles in the posterior portions of the body causes the proboscis to be thrown forward, and, conversely, extension of the head region forces it backward. In general the proboscis, together with the fluid of the rhyncocœl, tends to occupy the region of least pressure.

The relation of the cilia to the different movements is interesting. During forward movement the cilia are in active motion and constitute the chief organs of locomotion. If, however, the forward movement ceases suddenly, or if the head be slightly drawn back, the cilia in the part affected stop their movement and remain nearly perpendicular to the body surface. If the animal remains quiet for a short time the cilia may begin to move slightly. It is difficult to determine whether this movement affords any definite impulse in either direction, but observation indicates that there is a very slight backward current along the body. When the head and anterior portions of the body are suddenly and violently drawn backward, as often occurs, or if the animal begins to move backward, the cilia of the contracting region are laid flat against the body, all pointing forward, and resume their usual position when the backward motion ceases. The body is at all times covered with a thin layer of slime, and it is possible that the turning forward of the cilia may be simply the result of the backward movement of the body through the slime. Observation of the head region, which is constantly undergoing contraction and extension, shows a beautiful play of the cilia, and often in the rapid but very slight contractions without actual backward movement, the cilia over a considerable area are all instantaneously turned forward against the body, perhaps to reappear almost immediately. The rapidity and uniformity of their change of position render it probable that it is the result of a definite stimulation similar to that causing reversal of the cilia in many other forms.

I have not been able to find any indications of actual reversed beating of the cilia causing backward movement of the body. The backward movement is apparently brought about wholly by muscular contractions, the cilia being laid against the body and pointing forward, so that they offer no resistance, but remaining motionless or making very slight indefinite vibrations. These conclusions agree well with those reached as the result of macroscopic observations on the moving animal. Stichostemma does not appear to glide backward, but accomplishes this movement by violent muscular contractions as described above. Except when the stimulation is very intense and sudden, it is more likely to turn the head back upon the body and thus to change its direction of movement, than it is to move bodily backward.

As in other nemerteans and in turbellaria, the body is always covered with a thin layer of slime or mucus secreted by the dermal glands. Any stimulation or irritation causes an increase of this secretion to such an extent that the animal becomes enveloped in a thick layer of the substance. The animal is able, like many other related forms, to move beneath the surface film, and presumably this secretion is an important factor in locomotion here and elsewhere.

Small dishes in which a number of specimens are kept become filled with long strands and masses of the slime, in which the animals move about. The accumulation of the secretion does not appear to injure the animals in any way. Wilson ('00) has noted the large amount of slime secreted by Cerebratulus, and his observations are paralleled by my own. Certainly for so small a form as Stichostemma the amount of this slime secreted is extremely large.

RESPIRATION.

Respiration undoubtedly occurs through the surface of the body. The swallowing of water which Wilson ('00) has observed in Cerebratulus has never been seen in Stichostemma. The animals are apparently sensitive to changes in the oxygen content of the water, but their small size and the absence of a cuticle probably render special respiratory organs unnecessary.

FOOD.

The only food which the animal is known to take consists of specimens of Nais which are captured and gradually drawn into the alimentary canal. The actual capture of these animals has never been observed, although in several cases they have been seen in the partially digested condition in the alimentary canal, and in one case a specimen was found with a large Nais partly swallowed. The Nais was as long as its captor, and although half its body was in the alimentary canal of the nemertean the free portion made active movements. The nemertean was comparatively quiet, but at short intervals the mouth was widely opened and the body extended, and in this manner the Nais was drawn further into the alimentary canal. It could be clearly seen through the body wall of the nemertean that digestion of the annelid was proceeding very rapidly. Later a part of the Nais was disgorged, and some portions were seen to be completely disintegrated, while others which had been in the alimentary canal only a few minutes, ten to fifteen, showed distinct evidences of digestion. This rapid digestion of the food was also observed by Wilson ('00) in the case of Cerebratulus.

It appears extremely probable that the food is captured in the manner which Wilson ('00) has described for Cerebratulus, though I have never observed it. Indeed, there is a striking similarity between this form and Cerebratulus, both in the nature of the food and in the method of taking it. In the cases of both an actively moving annelid forms the food, being attacked and overpowered by the nemertean, and in both cases the prey is often as large as its captor and always more active. I have not been able to determine whether Stichostemma always begins the process of swallowing at the posterior end of the body of its prey. In the one case of feeding actually observed, the head of the naid had been broken off completely and lay in the slime secreted by the nemertean, but the free end of the annelid was apparently the anterior end from which the head had been broken. In the bodies of the naids which had been completely swallowed digestion had always proceeded so far that it was impossible to determine with certainty which was the anterior end.

The feeding apparently takes place only in darkness, or in light of little intensity, and therefore occurs normally during the night. During the day the nemerteans may remain in direct contact with the naids in the interstices of the masses of algæ, but apparently do not attack them. The next day, however, or after a few hours in darkness, the naids are fewer in numbers and the intestines of the nemerteans indicate very distinctly a recent meal. The failure to observe the actual capture and, in all but the one case mentioned above, the swallowing of the food, is probably due to the fact that the nemerteans are easily disturbed by a jar or movement of the dish containing them, and especially by the light. In such cases they probably release the prey or disgorge it, if partly swallowed, as in the case described above.

There is no direct evidence that the adult animal takes other food under normal conditions. The fæces, so far as recognizable as such, always contained the setæ of naids. Moreover, specimens have been kept for weeks in jars with many other animal forms, Protozoa, Turbellaria, rotifers, copepods, ostracods, etc., but no traces of any of these forms have ever been found in the alimentary canal.

The nature of the food of the young individuals is a matter of interest. When first hatched they are less than a millimeter in length. Probably they do not take food immediately, but they certainly feed when from one to two millimeters in length. The food at this time probably does not consist of naids, for it is difficult to understand how these small animals could capture any except the very smallest. I am inclined to believe that they feed upon other small forms during these early stages, though I have no direct evidence upon this point.

I have often suspected the animals of eating each other. In jars containing a large number of specimens there is always a remarkable decrease in numbers during the first weeks, and the walls and bottom of the jar do not show the whitish disintegrating masses that are always found, even after several days, in dishes where isolated specimens die. Moreover, it is the smaller animals that disappear, those remaining being of large size and appearing well fed. I think the circumstantial evidence in favor of the view that the worms readily devour members of their own species is very strong, but here again I have not been able to make actual observations.

The animals are capable of living for a long time without food. Single specimens have been kept for more than three months in jars of clear water with no other life except probably a very few Protozoa. In one case a jar containing a number of individuals was kept for six months. Three of the animals survived during this time.

During starvation a great reduction in size occurs. During the earlier stages the animal grows somewhat more slender, but later its length is also greatly reduced. In the case mentioned in the preceding paragraph the three specimens found at the end of the six months were less than five millimeters in length, though of about the normal proportions. When placed in the jar the specimens were of average size, *i.e.*, from twelve to fifteen millimeters in length. The reduction in size was wholly due to lack of food.

The starving forms usually acquired after a few weeks a blackish pigmentation, granules of black pigment being deposited in the body wall and increasing in abundance until in some cases the body had lost its light yellowish color and become a dull, dirty brown. In such cases microscopical examination showed the whole surface of the body to be dotted with small granules of black pigment. This pigment is not altogether absent in newly captured and apparently well fed specimens, but is usually not sufficiently abundant to have any appreciable effect upon the general coloration of the body. It undoubtedly corresponds to the pigment mentioned by Montgomery ('95, pp. 99–100) as occurring as an interstitial tissue.

The increase in the amount of pigment is undoubtedly connected with some alteration in the metabolism. It is possible that it is not directly connected with starvation but with some other effect of captivity; but, as far as my own experience is concerned, it appears in specimens which have been without food for some time. Decapitated specimens or pieces of the body, which may live for months, sometimes become distinctly brown or blackish.

Reaction to Stimuli.

As regards the reactions of the animal to stimuli, it is not intended to give here the results of extended experimentation. Some work has been done along these lines, but the results are reserved for a later time.

PHOTOTAXIS.

The most conspicuous reaction is the reaction to light. The animal is negatively phototactic for even moderate light intensities. The response is very distinct and definite. If a number of animals in a dish or jar be brought suddenly into diffused daylight, each begins almost immediately to move in the direction away from the source of light. Within a few seconds every animal in the dish is moving in this manner. Arrived at the opposite side of the dish, the animals do not immediately come to rest, but move about restlessly, following the sides of the dish, or in some cases even turning back toward the light for a short distance. The final result of these movements in a cylindrical jar is the aggregation of the worms in the region of least light intensity, not at the point farthest from the light but on the two sides at a point midway between the points farthest from and nearest to the light, where a large part of the light is shut off by the walls of the jar. In this respect these animals resemble Planaria (Loeb, '93), with the difference, however, that they are more restless and do not form such distinct and well-marked aggregations under these conditions as does Planaria.

In jars kept in a dark closet or in diffuse daylight on dark, cloudy days or toward night, the worms crawl about freely; *i.e.*, they are not distinctly negative for very low intensities. Examination of a jar during the night shows the worms to be active. They are thus evidently nocturnal in habit like Planaria.

Animals from which the whole head, including eyes and brain, has been removed, react to light in the same manner as do normal animals, but the reactions are slower and less exact (Parker and Burnett, '00).

The question as to whether the reactions of Stichostemma are strictly speaking phototactic or photopathic, whether two different kinds of reaction occur, is perhaps not easily decided. Certainly, so far as experiments already made indicate, there is nothing in the reactions of the animals to light that cannot be explained as due to the effect of different intensities without relation to the direction of the rays (Holt and Lee, '01).

THIGMOTAXIS.

The thigmotactic reaction is positive and distinct. The animal shows a strong tendency to crawl into interstices and is usually found in masses of algæ. In clear water it will commonly select the angle between bottom and sides of the jar and gradually come to rest there.

Several specimens in a jar of clear water will often aggregate in a single mass, crawling over and between each other and finally becoming nearly quiet.

A single individual, when it changes its course of movement, does not commonly make a curve but turns the head directly back against its own body and retraces its course. Undoubtedly the animal reacts thigmotactically to its own body. In a similar manner on coming into contact with the body of another individual, or indeed any object, the worm crawls along its sides or edges, seeking the spots where the greatest portion of its body is in contact with surfaces.

FORMATION OF "CYSTS."

Since the formation of the cyst-like slime covering, mentioned above, appears to be more or less closely connected with the thigmotactic reactions of the animal, it is discussed a little more fully here.

As noted above, there is a considerable increase in the amount of slime secreted when the animal is irritated in any way. Any strong stimulation, *e.g.*, strong light, handling in a pipette, etc., appears to cause this increase in some degree. Animals placed in a jar of perfectly clear water without algæ or other places of concealment show a tendency to settle in accumulations of their own slime, and it appears, in some cases at least, that the secretion becomes more dense under these conditions. It often happens that within a day or two an animal becomes surrounded by a dense coat of somewhat elastic slime, which even after removal of the animal retains a more or less definite form. Within this slow movements may go on continuously. Sometimes the body is so closely coiled that the covering is almost spherical, or the body may simply be bent back upon itself at one or two points, thus giving the covering an elongated form. The worm often remains in this covering for days or even for weeks, but may leave it at any time. That the animal is not incapable of making its way out is shown by the fact that violent stimulation will usually cause movements of sufficient force to rupture the wall of the covering and free the enclosed worm. The most interesting fact, and one which, as I believe, throws some light on the nature of this phenomenon, is that even after repeated stimulation or after rupture of the wall with needles, the animal in many cases exhibits an apparent reluctance to leave the covering. The head is protruded, makes the usual searching movements, and then is withdrawn again, and the worm continues its slow movements within the cavity of its case.

I believe that the enclosure of the animal within this secretion, and its apparent reluctance to leave its covering, are the result of the strong positive thigmotaxis which other actions show to be present. In a jar of clear water the slight accumulations of slime, which are the result either of irritation by strong stimuli or have been formed by the continuous secretion of slime at some particular spot where the animal has rested for a time, serve in some degree as a contact stimulus, and the worm tends to remain in or about them. Continued secretion leads to the formation of a more or less definite coat of slime, within which a cavity is formed by the continuous crawling of the worm. Various parts of the coiled and twisted body stimulate the sensitive head, giving the sensation of contact, and the head may often be seen to force its way in between two moving coils of the body, the whole body following. Thus the animal is constantly forming new figures and arranging its body in complex coils within the slime. From time to time, if the animal is well fed, the fæces and intestinal mucus are added to the wall, which thus becomes whitish and more opaque. Within the covering, then, the impulse which leads the animal to seek contact with surfaces is satisfied, and a strong stimulus is necessary in order to induce emergence. This latter fact is clearly evident from the apparent reluctance noted above to leaving the covering, even after violent stimulation. The head being protruded finds no contact surfaces except the flat glass, and is again withdrawn. In some cases worms which had been removed from the mucous coverings happened to come into contact with the latter again in their wanderings, and after crawling about over them reëntered them, thus showing in the clearest manner possible the thigmotactic nature of their preference for these cyst-like coverings.

Another interesting habit which these worms exhibit is closely related as regards its causes and nature to that just described, and is also clearly thigmotactic. In many cases, in their restless wanderings after introduction into jars of clear water, the worms reach the surface. They may crawl anywhere upon the surface film, but prefer the margins, where the surface of the water curves slightly upward toward the glass. Undoubtedly the surface tension of the water affords a certain resistance to their movements here and calls forth a contact sensation. Into this angle between the surface film and the side of the jar the worms push their way and then crawl completely out of the water and up the side of the jar. The slime secreted by the surface prevents immediate desiccation, but becomes thicker and harder as evaporation goes on, and thus in even greater degree than the slime coverings in the water affords the sensation of contact. The worms never attempt to return to the water, but remain within the cases thus formed until death ensues, which occurs within a few hours. The whole series of reactions leading to the emergence from the water and the failure to seek it again is thigmotactic.

If the animals do not leave the water within the first twenty-four hours after being placed in the clear water they very rarely do it afterward unless they are again set in active motion by some strong stimulus. I have kept worms in a jar of this kind for three months; the only specimens which left the water did so within the first day or two, although the conditions within the jar remained equally unfavorable during the whole period.

The fact that the animals tend to leave clear water only during a short time after being placed in it is undoubtedly due to temporary excitement in consequence of handling, strong light, etc., when first introduced into the jar. For some time they are very active and many of them reach the angle between the surface of the water and the sides of the jar. Some of them force themselves into the angle with powerful movements and thus leave the water. Later the movements become less rapid, and even when they happen to reach the angle between the water and the side of the jar they content themselves with following it or remaining quietly in it. Moreover, others have meanwhile come into contact with other individuals or with slight accumulations of slime and tend to remain quiet. It is probable that there is also some degree of acclimatization to the new conditions, so that they in themselves fail after a time to stimulate the animal as strongly as they did at first.

It is clear that the formation of these coverings cannot be regarded as constituting a true encystment. The animal does not enter a quiescent stage within the covering, nor is it enabled to survive conditions which would otherwise cause death, except that its life may be lengthened for a few moments by the formation of the covering after it leaves the water, or that it may in some cases escape the attack of predatory enemies by formation of the slime covering.

The formation of the coverings is the result of the following conditions: the surface of the body is constantly secreting slime, and stimulation or irritation causes an increase in the amount of the secretion, perhaps also some change in the quality; and secondly, accumulations of this slime are of sufficient density to call forth in some degree the positive thigmotactic reaction.

On the other hand, it is quite possible, and even probable, that the process of encystment might arise in some such manner as this in a positively thigmotactic animal. Indeed, in the present case a change in the quality of the secretion, rendering it less permeable to water, appears to be the only, or at least the principal, modification necessary for the formation of a true cyst. It is possible that in Stichostemma the secretion may become so modified in time that the animal will succeed in tiding over the dry seasons by becoming encysted, and will then become capable of living in shallow, temporary pools, which dry up during a part of the year.

At present, however, the formation of the slime coverings cannot be regarded as an adaptation to particular conditions. It is merely an incidental result of certain reactions of the animal which have no relation to lack of water. In those cases where the animal leaves the water the result is always or nearly always death. If the nature of the secretion should for any reason undergo change in some individuals or races, selection of those secreting the most impermeable covering might occur.

The question as to whether the emergence from the water ever occurs under natural conditions requires a brief consideration. It might be supposed that in nature the animals can always satisfy the thigmotactic impulse among the vegetation and débris beneath the surface ; but since the reaction is so distinct, and includes so large a proportion of the animals in clear water in the laboratory, I can scarcely believe that it does not occur sometimes in nature, and probably very often. Moreover, as is noted below, foulness of the water often induces the emergence, and in the lagoon where these worms are found the water in certain localized regions may become stagnant to a considerable degree in consequence of the decay of the luxuriant vegetation. I believe, therefore, that the animals must leave the water frequently in nature, and that these individuals are usually eliminated. It is possible that an animal which has left the water may occasionally find its way back to it, but I have never been able to observe a case of this kind in the laboratory, though I have often looked for it.

It appears probable, however, that the change from an aquatic to a terrestrial habit may be due, at least in such forms as the turbellarians and nemerteans, to a positive thigmotactic reaction which leads the animal to force itself into the angle between the surface film of the water and the substratum and thus to leave the water in the manner so well illustrated by Stichostemma. Perhaps Stichostemma itself will become able in time to resist evaporation and to obtain its food under the altered conditions and so acquire a more or less completely terrestrial habit. At any rate this thigmotactic reaction to the surface tension of water must be regarded as one of the causes which may induce creeping aquatic forms to leave the water.

CHEMOTAXIS.

Among the chemotactic reactions the most conspicuous under conditions approaching the normal are the reactions to the composition of the water. In general the animals show some tendency to aggregate where the oxygen content is greatest. Placed in jars with masses of algæ and other animals, and kept where formation of oxygen by the plants does not occur in any marked degree, the animals aggregate at the surface as the water becomes foul. Under these conditions they are found either among the algæ just beneath the surface or crawling or resting beneath the surface film or about the margins. Furthermore, as the water becomes foul, animals which did not leave it earlier now crawl up the sides of the glass and die there. This reaction is in this case doubtless a mixed negative chemotactic and positive thigmotactic reaction; that is, the impulse to seek the surface is given by the increasing lack of oxygen or the increasing quantity of decomposition products in the water. Having reached the surface and being perhaps still restless in consequence of the chemical stimulus from the composition of the water, the worm leaves the water in response to the combined stimuli, and thus dies more quickly than it would if it remained in the water, since it possesses a high degree of resistance to the effects of foul water.

ENEMIES.

In general, Stichostemma appears not to suffer greatly from the attacks of predatory animals. Mutilated specimens are rarely found, though experiments show that even relatively small pieces of the body may live for weeks. Montgomery ('95) stated that cyprids destroy *Stichostemma eilhardi*. Under ordinary conditions I have never been able to observe that cyprids actually attacked the active, healthy specimens. Occasionally they crawl over the body, but very soon leave it again, apparently without inflicting injury. In a series of experiments in which two or three specimens of Stichostemma were placed in small jars of clear water with hundreds of cyprids, it was found that although the worms remained alive and apparently uninjured for a day or two, they were finally completely devoured. When specimens of Stichostemma were cut in pieces and thrown into a jar containing numerous cyprids, they were rapidly devoured. In other experiments two or three worms were placed in a small dish with several dragonfly nymphs, which were given no other food. The nymphs occasionally attacked the worms, sometimes biting them in two. Within two days the worms were usually bitten into several pieces or killed, but not devoured. At the conclusion of the experiments the same nymphs took Gammarus eagerly, thus showing certainly that they were not satiated with food. Their attacks upon Stichostemma were often observed. The worms were picked up and held by the large labium for a moment, sometimes bitten completely through and allowed to drop almost immediately, or occasionally bitten at various points and badly crushed, but not eaten so far as could be observed. The worms frequently crawled over the surface of the nymphs without exciting any response from the latter. It is of course possible that the nymphs devour small portions, but they are certainly not sufficient to satisfy the hunger of these voracious feeders.

The worms are unable to escape from predatory forms by rapid movements, for their movements are all relatively slow. It was very evident during the experiments that the nymphs often saw the worms when at some little distance from them and approached them, perhaps reaching out and grasping them for a moment only to let them drop again. In such cases the nymphs had not the slightest difficulty in approaching the worms.

It would appear that Stichostemma, especially when filled with eggs, would afford an inviting morsel for many predatory aquatic forms, and that without some means of protection its existence in the presence of such forms in the large numbers that occur would be impossible. Its conspicuous color and slow movements render it easy of discovery and approach by those forms which use the sense of sight in finding their prey. Nevertheless the adult, the young, and the eggs appear to remain unharmed in most cases.

I am inclined to believe that the abundant secretion of slime from the surface of the body and its increase under irritation renders Stichostemma more or less undesirable as an article of food. The slime is rather tenacious, and it is possible also that small animals are unable to pierce it and thus reach the body of the worm.

The bodies of the worms when cut into pieces possess a slight but distinct fishy odor. As was determined by direct experiment, no decided taste is present. It may be, however, that the slime or the body possesses some quality which renders it disagreeable to at least some animals; but even if this is not the case, the presence of the slime must afford a certain amount of protection against attacks, at least against those of small animals.

In connection with the possibility that the slime may afford a means of protection, it is interesting to note that in the experiments with the cyprids the nemerteans became very quickly surrounded by the slime covering and remained enclosed in it until they were artificially removed the next day. In all probability the rapid formation of the slime "cysts" was the result of the incessant irritation of the surface of the worm by the cyprids crawling over it. As it formed and thickened, this slime furnished a covering which the cyprids could not penetrate, or could penetrate only with difficulty after some time.

SEXUAL RELATIONS.

According to Montgomery, *Stichostemma eilhardi* is a protandric hermaphrodite. *Stichostemma asensoriatum* is hermaphroditic, but certainly not protandric. I have never found a purely male specimen of any size. The gonads are visible in the living animals, and the small oöcytes can be seen very early in their history. Moreover, eggs and spermatozoa leave the gonads together when the eggs are laid. By subjecting the animal to pressure the spermatozoa may often be seen in the same gonads with fully grown oöcytes, and when the egg leaves the body there are nearly always a considerable number of spermatozoa sticking to its membrane. The contact with the water apparently serves as a stimulus, and fertilization as well as maturation occurs very soon after the egg leaves the body.

From these relations it is evident that self-fertilization is possible. As a matter of fact it is undoubtedly the rule. In a large number of cases specimens which had been isolated for a week or two laid eggs, and these were always fertilized and developed. I have often removed the eggs artificially by cutting the animal into pieces, and in every case where fully grown eggs were present, fertilization occurred. The fully grown eggs can be distinguished by the fact that no peduncle of attachment is present. In younger eggs the membrane is incomplete, and the egg is in continuity with the protoplasm of the gonad through a small stalk or peduncle. I have never been able to obtain unfertilized eggs. Finally, sections of the animal with full-grown egg cells always show the spermatozoa clustered over the surface of the egg or massed in some part of the gonad, while specimens with younger egg cells show stages of spermatogenesis, and still younger stages show merely the young oöcytes and the sperm mother-nuclei. The spermatozoa, or some of them, always pass out with the egg, and I believe that each egg is fertilized by the spermatozoa of the same gonad. There is absolutely no evidence that spermatozoa reach the oöcytes in any other manner. None have ever been found in the slime which encloses the egg after it is laid in the normal manner. None have been found in the water in which many specimens had been kept. But I think the strongest evidence in favor of self-fertilization lies in the fact noted above, that spermatozoa can be seen upon the membrane of each egg cell and that the penetration of these spermatozoa can be observed immediately after the egg cell reaches the water. As in *S. eilhardi*, the genital pores are not preformed, so that spermatozoa cannot enter from the exterior before egg-laying unless they make their way through the body wall. That this is not the case is shown very clearly by the time of their appearance, their relations to the remainder of the gonad, and by the fact that fertilization itself always occurs outside of the body. The structure and relations of the various parts of the gonads and the oögenesis afford a large number of interesting facts, but these need not be discussed in detail here. There is strong evidence that each gonad is always hermaphroditic after its original formation, and that egg cells and spermatozoa almost always develop together.

I believe that cross-fertilization occurs very rarely in Stichostemma in nature, even if it ever occurs. The egg cells when they pass out of the body are immediately enclosed in the slime from the surface, and the spermatozoa with them. While it is, of course, possible that a few spermatozoa might make their way through the slime to the water and then again through the slime surrounding the eggs of other individuals, the most careful observations have never given the slightest evidence that this actually occurs. Furthermore, if it did occur, the second set of eggs would be fertilized before such a spermatozoön could reach them.

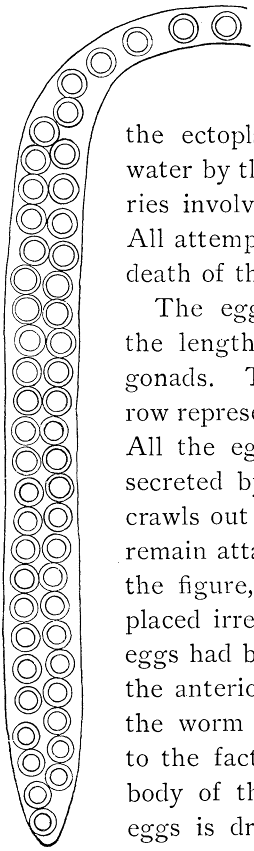
The only possible conclusion is that self-fertilization is the rule in *S. asensoriatum*.

As a rule only one egg is formed in each gonad, but exceptions are not uncommon, though more than two egg cells in a single gonad have never been observed.

EGG-LAYING.

The normal process of egg-laying has not been observed in Stichostemma, although numerous egg strings have been found in the jars in which the animals were kept. The extrusion of eggs from the body in consequence of irritation or injury has often been observed. If an individual containing fully grown eggs be cut into several pieces, the eggs, or many of them, will often be extruded after a short time, apparently as the result of contractions following the injury. The first step in the process is the breaking of the body wall at a definite point, *i.e.*, the appearance of the pore. Immediately after this the egg begins to flow out. The diameter of the pore is very small, so that the egg is greatly distorted during its passage. Indeed, it appears to flow out like rather thick fluid. At first a small, rounded, transparent protuberance appears at the outer opening of the pore; this is the egg membrane. Then the yolk granules and cytoplasm may be seen flowing out through the pore, and the part outside increases continually in size as more and more of the egg substance reaches it. The part of the egg outside the pore and that still within the body are connected by the slender band of egg substance which is passing through the body wall. The nucleus usually remains in the body until at least half of the volume of the egg has flowed out. The small size of the genital pore presents an obstacle to the passage of the nucleus, and often the passage of the egg ceases until some contraction of the body forces the nucleus through the narrow duct and it suddenly pops out through the pore. After the passage of the nucleus the remaining portion of the egg flows out rapidly, and the whole egg assumes almost immediately its spherical or nearly spherical form. The spermatozoa on the egg membrane can often be seen clearly during the passage of the egg, and it is evident that their movements begin as soon as they reach the water.

It is difficult to understand how definite areas of differentiated protoplasm could persist or maintain their proper position during this outflowing of the egg. To all appearances, at least, the egg flows out like a thick liquid under some pressure, and it appears scarcely possible that its parts maintain the same relative position before and after its emergence. The whole egg is enclosed, however, in a very thin layer of transparent protoplasm, an ectoplasm, and if the pressure is too great this layer is ruptured, and the cytoplasm and yolk flow out as a viscid, granular fluid, which tends to reassume the spherical form. It is evident that the cytoplasm is elastic and that the reassumption of the spherical form by the egg is due to this elasticity. Eggs in which the ectoplasmic layer has been ruptured do not develop, or at least development is confined to the uninjured portion. All such cases of partial development die in early stages. When the yolk is exposed it appears to absorb water very rapidly, the egg or the injured part of it increases in size and becomes more transparent, and sections show vacuoles in place of the yolk granules. The death of the egg always accompanies or follows this absorption of water. Apparently the presence of the ectoplasmic layer prevents this absorption of water by the yolk. The egg is very sensitive to injuries involving the rupture of the ectoplasmic layer. All attempts to kill a part of the egg ended in the death of the whole a little later.



Egg string of Stichostemma.

The eggs are laid normally in strings of about the length of that portion of the body containing gonads. The eggs are deposited in two rows, each row representing the eggs from one side of the body. All the eggs are enclosed as they emerge in slime secreted by the dermal glands, and then the worm crawls out from between the two rows of eggs which remain attached to the substratum. As shown by the figure, the eggs at one end of the string are placed irregularly, as if the secretion enclosing the eggs had been stretched. This end is undoubtedly the anterior end of the string, *i.e.*, the end at which the worm leaves after laying, and its form is due to the fact that some of the slime adheres to the body of the worm, and together with the enclosed eggs is dragged after it as it moves away.

The cleavage of the eggs is typically spiral, all the cells being nearly equal in size during the earlier stages. The development is of the direct type. The surface of the embryo becomes ciliated, and it moves about within the egg membrane for a day or more before leaving it. The spherical embryo begins to elongate after three or four days, leaving the membrane when about one-half millimeter in length. The young animal possesses at first four eyes, the posterior pair of the adult being formed at a later stage than the others, thus probably indicating their later origin in the species. I have not been able to ascertain whether the food of the young is the same as that of the adult.

THE BREEDING SEASON AND ITS RELATION TO THE ENVIRONMENT.

The breeding season of Stichostemma extends from May to November or December, according to the temperature of the water. Practically every specimen taken soon after the ice melts in the spring contains the growing oöcytes in the gonads, and these reach their full size, and egg-laying begins as soon as the shallow water along the shores becomes sufficiently warm. During the whole of the season from May to November the very young worms are abundant in sizes, varying from a millimeter up, and the eggs are often found in the algæ with the worms.

Egg-laying occurs freely in the laboratory. Often when the algæ containing worms are brought in and allowed to stand for twenty-four hours, a large number of egg strings will be found near the surface and on the sides of the jar. Apparently the eggs are always laid during the night or in darkness when the animals are moving about freely. Even in jars of clear water and without food the eggs are often deposited abundantly during the first few days of captivity, but individuals which do not lay eggs during that time are not likely to do so later, though, as experiment shows, they contain fully grown oöcytes.

Eggs can be obtained in the laboratory at any time during the year when the worms can be found in moderate numbers. During December many individuals with oöcytes at least half grown are found. In nature these eggs are probably not laid until the following spring, but if the worms are kept at room temperature in the laboratory a number will usually deposit eggs within a week or two, and this will occur even if the animals are kept without food. By these observations and those made upon animals under natural conditions during nearly two years, I am convinced that the limits of the breeding season are determined chiefly by the temperature of the water. Probably food is actually an important factor, but its abundance is also more or less dependent on the temperature of the water, so that the latter must be regarded as the most important factor in determining the time of egg-laying.

That food is not of prime importance is clearly shown by a large number of observations in the laboratory. In animals which contained only small oöcytes when taken, and which are kept in clear water without food, the growth of the oöcytes will continue, and within a week or two eggs may be laid. This has been found to be the case even during the winter, and it shows very clearly that the important factor is the degree of temperature which permits the metabolism necessary for the formation of the yolk and the growth of the oöcyte in general. In such cases the oöcytes complete their growth either at the expense of the other tissues or some store of nutritive substance within the body. The body of the animal may even decrease somewhat in size during the growth of the oöcytes. In some way the energy of the body is applied to the completion of these important products, even at the expense of the remainder.

If an individual containing young oöcytes of small size be cut transversely near the middle of the body, and the pieces placed in clear water without food, both will usually live for months. The posterior piece does not regenerate, but the oöcytes grow much more rapidly in it than in the anterior half, and may attain their full growth and be capable of fertilization and development before those contained in the anterior half have reached more than half or two-thirds of their full size. I can explain this fact only on the basis of the difference in activity of the two halves. The anterior half, possessing a head and brain, behaves like a normal animal, moving about actively, while the posterior half, being without a brain and never regenerating a head or brain, is much less active and less sensitive to stimuli. In other words, much of the potential energy of the body which is employed in the anterior piece in producing the various movements, and probably in a more intense general metabolism, is directed in the posterior piece to the completion of the growth of the oöcytes. These cases afford a most instructive example of the relation to each other of some of the various so-called vital activities. In the presence of the brain and anterior portion of the nerve cords the bodily movements appear to take precedence over other functions, even though the sexual products are not completed. But when the anterior portions of the nervous system are absent the animal, being without the power of regenerating the lost parts, is less affected by stimuli, and a larger portion of the potential energy is devoted to the elaboration of the sexual products. This process must, as a matter of fact, be regarded as the function next in importance to that of carrying out the normal movements and responses to stimuli.

Mention has been made of the fact that animals kept in captivity without food are not likely to deposit their eggs after the first week or two of captivity, even though artificial removal of the egg cells may show them to be capable of fertilization and development. In such cases the fate of the egg cells is quite remarkable. They may remain unchanged in appearance for two or three weeks, but after a time evidences of alteration in their structure are visible even in the living animal. The egg cells become less opaque in appearance and a clear space appears about each, apparently the result of thickening and swelling of the membrane. Later many of the eggs break up into round masses and granules, which sections show to be merely disintegration products and not cells. But the more remarkable fact is that, as the changes go on, many or all of the eggs pass out of the gonads and come to lie within the alimentary canal, where they serve as food and are actually digested. Continued observation from day to day of isolated specimens leaves no doubt that this actually occurs. In many cases the egg cells are still intact when they enter the alimentary canal and can clearly be seen there, moving to and fro with the movements and contractions of the body. Disintegration and digestion of the egg goes on rapidly in the alimentary canal, however, and in a day or two the whole intestine may be filled with a granular mass which represents the cytoplasm and yolk of the egg. In case disintegration of the egg has begun before it enters the alimentary canal, it very rapidly becomes a granular mass recognizable as an egg only through its known origin.

That these disintegrating eggs actually serve the animal as food is evident from the fact that in a number of cases the passage of the eggs to the alimentary canal and their digestion was followed in a few days by the appearance and partial growth of new oöcytes in the gonads, each individual worm being isolated meanwhile in clear water and without other food during the whole period. In cases where the eggs were normally laid by similarly isolated specimens, new oöcytes appeared only when the first set had been laid almost immediately after the beginning of the experiment, so that the animal was comparatively fresh and probably still contained a certain surplus of nutritive material. Moreover, these oöcytes never reached a large size and usually underwent disintegration at a later period.

The manner in which the disintegrating egg cells reach the alimentary canal is somewhat obscure. Rupture of the walls of the gonad and the intestine is necessary. I believe that this rupture is brought about chiefly in consequence of the increasing disproportion between the size of the body and the size of the egg as the starving animal decreases in size, and that finally the egg becomes too large for the lateral regions of the body and is forced into the alimentary canal by the movements and contractions of the body. A study of sections reveals a decreasing thickness in the walls of the intestine and gonads, as well as other histological changes, but these need not be discussed here.

The passage of the egg cells to the intestine occurs in pieces which have been deprived of head and brain, as well as in normal individuals.

ABSENCE OF FISSION.

Benham ('97) has described a process of spontaneous fission in Carinella which probably serves as a means of distribution of the sexual products, and Wilson ('00) states that Cerebratulus fragments spontaneously at the close of the breeding season, apparently as a means of getting rid of a portion of the body which has become of little use.

I have never observed spontaneous fission or fragmentation in Stichostemma, and have never found pieces or fragments which might be the result of such fission. Occasionally specimens are found which show slight constriction at some points, but isolation and continued observation of these individuals have always been without result. These constrictions appear not only in individuals with mature sexual products, but in other stages, and usually disappear after a few days. Moreover, they are frequently irregular, being more pronounced on one side of the body than on the other. I am inclined to believe that they are merely the results of slight injuries, for slight cuts in the sides of the body produce results which are indistinguishable from those found in freshly collected specimens.

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